# ESTIMATION OF EXPOSURE OF PERSONS IN CALIFORNIA TO PESTICIDE PRODUCTS THAT CONTAIN BENOMYL

by

David Haskell, Associate Environmental Research Scientist

Louise Mehler, Associate Toxicologist

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California Environmental Protection Agency

Department of Pesticide Regulation

Worker Health and Safety Branch

1220 N Street, P.O. Box 94271

Sacramento, California 94271-0001

## ABSTRACT

Benomyl, (methyl 1-(butylcarbamoyl)-2-benzimidazole carbamate) is a broad spectrum fungicide registered for use on a wide variety of agricultural crops and for home owner use on lawns, ornamentals and home garden vegetables. The risk characterization document for benomyl, prepared by the Medical Toxicology Branch of the Department of Pesticide Regulation, indicates that a metabolite of benomyl, methyl 2-benzimidazole carbamate (MBC), has the potential to cause developmental toxicity in rabbits. The United States Environmental Protection Agency has classified benomyl as a group C oncogen (possible human carcinogen) in the Guidance Document for the Reregistration of Pesticide Products that Contain Benomyl as the Active Ingredient (June 1987). Dermal absorption of benomyl is estimated to be approximately 10% over a 24-hour period. Benomyl degrades primarily by removal of the butylcarbamoyl group, leaving MBC and butyl isocyanate. Animal feeding studies have identified the primary metabolites of benomyl as MBC, its hydroxylated metabolite 5-OH MBC and 2-aminobenzimidazole and its 5-hydroxylated metabolite. Excretion of metabolized benomyl in the urine and feces of mice was found to be 95% complete 96 hours after oral administration. Exposure data from the Pesticide Handlers Exposure Database was used to quantify the occupational exposure to benomyl from applying Benlate® SP Fungicide. The estimated dermal exposure for flaggers, mixer/loaders and applicators ranged from 1.0-7.8 mg per workday (8 hours) with inhalation exposures ranging from 0.003-1.5 mg. Field workers pulling leaves or thinning shoots in a vineyard treated with Benlate® SP Fungicide at the maximum label rate could experience a dermal exposure of 25.9-31.7 mg of benomyl per day.

# APPENDIX B

## California Environmental Protection Agency
## Department of Pesticide Regulation, Worker Health and Safety Branch

## Human Exposure Assessment for Benomyl
**August 5, 1998**

### GENERAL PHYSICAL AND CHEMICAL CHARACTERISTICS

Benomyl (methyl 1-(butylcarbamoyl)-2-benzimidazolecarbamate) is a broad spectrum fungicide of low acute mammalian toxicity. The pure compound has a molecular weight of 290.3 and consists of colorless crystals with a vapor pressure of $3.7 \times 10^{-8}$ mm Hg at $25^{o}$ C (Barefoot, 1988). It decomposes at high temperatures or in the presence of either acid or alkali conditions. It is soluble in water to the extent of approximately 2 ppm and will form a 9.4% solution in chloroform, 1.8% in acetone and 0.4% in ethanol.

### EPA STATUS

The United States Environmental Protection Agency (U S EPA) has conducted several extensive reviews of the data supporting the registration of benomyl and has classified this compound as a Group C Oncogen (U S EPA, 1987). In regard to occupational exposure, the position document (PD 4) issued on October 29, 1982 ( U S EPA, 1982) required either cloth or disposable dust masks to be worn by mixer/loaders of aerial application equipment. The guidance document for the reregistration of benomyl products was issued in June 1987. Manufacturers were required to submit foliar and soil dissipation studies and additional dermal and inhalation studies. An interim worker reentry interval of 24 hours was established (prior to August 1992) on all crops treated with benomyl until the data can be generated. The Agency has also mandated amendments to the benomyl label to provide protective clothing for mixer/loaders and applicators. The required clothing is listed in the "Personal Protective Equipment" section of this assessment. To date, the primary registrant has continued to support benomyl in the reregistration process. The U S EPA is reviewing submitted data and waiting for additional data to be generated from the required studies that are in progress.

### USAGE

The benomyl product registered for agricultural uses has recently undergone a significant loss in uses for California crops. Uses on all ornamental crops, and on avocados and rice have been dropped from the Benlate® SP Fungicide label. Benomyl is still registered for use as a seed treatment, a bulb dip, and as a broadcast spray on conifers and many vegetable, field and orchard crops. The dip treatments require 8 oz. active ingredient (a.i.)/100 gallons of water. Seed treatment uses range from 4 to 16 oz. a.i. per 100 lbs. of seed. Sprays for crops are applied in the range of 2-16 oz. of a.i./acre. The application rates for the home/garden labels are 1-2 oz. of a.i. per 1,000 square feet of lawn and 0.5-1 oz. a.i. per 12.5 gallons of water on garden fruits and vegetables. Over 150,000 lbs. of benomyl were reported used in 1994 by the California Environmental Protection Agency (Cal/EPA), Department of Pesticide Regulation (DPR, 1996). The majority was used on almonds, celery, grapes, stone fruits and strawberries.

## FORMULATION

Two products formulated as a 50% wettable powder of benomyl, are currently registered in California. Benlate® SP by Du Pont Chemical is registered for agricultural uses and is packaged in one-pound water soluble packets. A second product, Green Light Systemic Fungicide with Benomyl, is registered for home-garden uses. The product manager at the Green Light Company has indicated that the product is currently registered only to cover the product that may still be in the channels of trade (Luedke, 1997). Du Pont Chemical is no longer selling technical benomyl for use in formulating home-garden products. The Green Light Company has ceased manufacturing this product and does not have any in storage. It seems appropriate to conclude that the home-garden use of benomyl will not exist in a year or two.

## LABEL PRECAUTIONS

The label signal word on all formulations is "Caution". This is primarily due to the fact that benomyl is a mild irritant to the eyes, nose, throat and skin. Labels advise the user to avoid contact with skin, eyes and clothing and to avoid breathing dusts and spray mists. In the event of contact with the concentrate or spray mixture, flush skin and eyes with plenty of water; for eyes get medical attention. The possibility of exposure causing a temporary allergic skin reaction for sensitive individuals is mentioned on the label registered for agricultural uses.

## PERSONAL PROTECTIVE EQUIPMENT

Workers with the potential for exposure to benomyl during application of Benlate® SP Fungicide or other work tasks must wear long pants and long-sleeved shirt or coveralls, full body chemical-resistant clothing, waterproof gloves and chemical-resistant footwear plus socks and a dust/mist filtering respirator. In addition, workers mixing and loading concentrate benomyl must also wear a chemical-resistant apron. A closed system is required for the transfer of the liquid mixture from the mix tank to the application tank. If the application is going to be made in an enclosed area like a mushroom propagation house, an organic vapor respirator for pesticides must be worn instead of a dust/mist filtering respirator. Farm workers entering treated areas prior to the expiration of the 24-hour reentry interval, must wear work clothing, waterproof gloves, chemical-resistant footwear plus socks. If an aerial applicator is using aircraft with an enclosed cockpit, only a long sleeved-shirt and long-legged pants, shoes and socks need be worn. However, a pair of chemical-resistant gloves must be available in the cockpit and be worn when entering or leaving an aircraft contaminated with pesticide residues. Flaggers must be in totally enclosed vehicles.

The use of a product formulated in water soluble packets in conjunction with the label requirement to use a closed system to transfer the liquid mixture complies with the definition of a "closed system" for California and federal regulations. The federal Worker Protection Standards (WPS) and the California regulations to implement WPS allow employees mixing and loading a category III pesticide with a closed system to substitute long-sleeved shirt and long pants or coveralls, and shoes and socks for the label-required PPE*. The WPS also permits flaggers working in an enclosed cab without air filtration, to wear only work clothing and the respirator required by the label for handlers. Although the product label does not address protective eye wear, the federal WPS and the California regulations to implement WPS, require eye protection to be worn by employees mixing and loading pesticides with a closed system operated under positive pressure*****. Since aircraft with enclosed cabs are the standard of the aerial application industry, the aerial applicator was assumed to be operating an airplane with an enclosed cab. However, for ground boom and orchard-vineyard air-blast applications the operator was assumed to be operating equipment with an open cab.

## WORKER ILLNESSES

Reports of illness attributed to exposure to combinations of pesticides which include benomyl are more common than those attributed to benomyl alone. This reflects the practice of using multiple fungicides to avoid selecting resistant strains. The majority of reports concern skin rashes. Since benomyl is known to be a sensitizing agent, it is possible that some of the rashes reported represent allergic dermatitis (Gargus, 1984).

During the years 1984 - 1993, eight systemic illnesses attributed to benomyl exposure were reported by the Cal/EPA, Department of Pesticide Regulation (DPR) (CDFA, 1985; CDFA, 1986; CDFA, 1987; Edmiston and Richmond, 1988; Mehler *et al.*, 1990; Mehler, 1991; DPR, 1993; DPR, 1994a; DPR, 1994b; DPR, 1995). In addition, for the same period, seven skin and three eye injuries were attributed to benomyl alone, while nine skin, seven eye, one involving both eye and skin and five systemic illnesses were attributed to exposure to benomyl in combination with other pesticides.

## DERMAL TOXICITY

Benomyl is known to provoke allergic responses in people, although the original tests on guinea pigs were negative for sensitization (Du Pont, 1986). Repeated tests indicated mild sensitization

* Current California regulations allow employees mixing and loading with a closed system to substitute work clothing, a chemical resistant apron, boots and gloves for full body chemical-resistant clothing. Protective eyewear must also be worn during mixing and loading with a closed system when making and breaking connections and during all hand and most ground applications.

of guinea pigs (Du Pont, 1986). Tests on rabbits and guinea pigs showed mild to moderate irritation at concentrations above 40% (Du Pont, 1986). No dermal $LD_{50}$ could be determined; the highest practical dose of 10 g/kg, (occluded for 24 hours) resulted in some weight loss without other apparent toxicity (Du Pont, 1986).

## DERMAL ABSORPTION

Dermal absorption was investigated using albino rats (Belasco *et al*., 1981). Benlate® (trade name of benomyl in wettable powder) labeled with $^{14}C$ was applied in water suspension to four square inches on the backs of rats at rates of 0.2, 2, 20 and 200 mg of product per rat. This corresponds to concentrations of 4, 40, 400 and 4000 μg a.i./cm². Groups of four rats each at each dose level were sacrificed at 0.5, 1, 2, 4 and 10 hours following dosing. The maximum blood level was reached within four hours with only a slight increase from the level observed after one hour. Urinary excretion was appreciable even during the first half hour.

Analysis at the U S EPA included an estimate of the maximum obtainable blood levels from a semilogarithmic plot of rat blood level versus dose rate. The rat data was plotted as a log-log plot of excretion versus dose rate and used to estimate a human absorbed dose (U S EPA, 1979). The conclusions were that the maximum potential blood concentration is less than 130 ppm, which was stated to be a non-toxic dose. A study by Jegier (1964) cited in the benomyl position document, concluded that a mixer/loader exposed dermally to 1.8 mg/kg/hour of benomyl would absorb 374 micrograms during the course of an eight-hour workday.

The assumptions involved in the U S EPA estimate of absorption by a mixer/loader differ from those that are standard at DPR. Computations by the U S EPA were limited to unprotected skin areas (260 square inches). Only the absorption that would occur during the workday was considered, and the amount of chemical on the skin was considered to accumulate hour by hour.

DPR policy is to consider exposure to the entire body, not just unprotected areas, and to compute absorption potential for a whole day's accumulation left in contact with the skin for 10-24 hours. This can be estimated from urinary excretion data provided in the dermal absorption study. The rate of urinary excretion was quite consistent at each dose level. Extrapolation of urinary recovery at 2, 4 and 10 hours to 24 hours results in apparent absorption of 10% of the 4 μg/cm² dose, 1.5% of the 40 μg/cm² dose, 0.3% of the 400 μg/cm² dose, and 0.1% of the 4000 μg/cm² dose. Since the dermal exposure from occupational activities is expected to average less than 5 μg/cm², the 10% absorption rate was used in the exposure assessment to calculate the absorbed dose from a dermal exposure.

## ANIMAL METABOLISM AND DEPOSITION

Benomyl degrades primarily by removal of the butylcarbamoyl group, leaving methyl 2-benzimidazole carbamate (MBC, or carbendazim) and butyl isocyanate (Kilgore and White, 1970). Butyl isocyanate degrades rapidly and irreversibly to carbon dioxide and butylamine

(Krupka, 1974). In water, the estimated half-life is 14 minutes (Moye *et al*, 1994). MBC is a fungicide of equivalent effectiveness and range to benomyl. MBC is considered by some to be the active form of the pesticide, especially since MBC is also the degradation product of another broad spectrum fungicide, thiophanate-methyl (U S EPA, 1982). The impression that conversion of benomyl to MBC was rapid and quantitative may be due to a laboratory artifact (Baude *et al*., 1973). A recent DFR study conducted by one of the registrants indicated the half-life in the field is much longer. DFR on grapes treated late in the season with 0.75 lb a.i./acre had a half-life of approximately 21 days (Powley, 1989). A similar study conducted on strawberries observed a half-life of about seven days (Mc Nally, 1990).

The fate of ingested benomyl was investigated in rats, dogs, cows and hens by Gardiner *et al*. (1974) and in mice, rabbits and sheep by Douch (1973). The registrant has submitted studies on oral, intravenous and dermal administration of benomyl to rats and mice (Belasco *et al*., 1981), (Haskell Laboratory, 1980a and 1980b). Excretion of benomyl in urine and feces of mice was found to be 95% complete 96 hours after oral administration (Douch, 1973). Following intravenous administration, elimination was over 95% complete in 24 hours (Belasco *et al*., 1981). Dosing of pregnant rats by gavage resulted in very early peaks of benomyl/MBC concentrations both in maternal blood and embryonic tissue (Haskell Laboratory, 1980a). The hydroxylated metabolite, 5-OH MBC, was eliminated more slowly, with a half-life of 2-3 hours in maternal blood and 4-8 hours in embryonic tissue. Douch also identified 2-aminobenzimidazole (2-AB) and its 5-hydroxylated metabolite as significant metabolic products of benomyl.

Although data have not been submitted on human metabolism, the studies of various animal species indicate reasonably rapid and quantitative elimination in urine of a sufficiently small set of metabolites that biological monitoring may be practical. The relevant animal data are summarized in Table 1.

**Table I Quantitation of Benomyl Metabolites in the Excreta of Various Test Species**

| Species | Reference | Source Administration | Route of Period | Collection Analyzed | Matrix | Percent of Dose | | | |
|---|---|---|---|---|---|---|---|---|---|
| Subject Recovered Species | Reference | Administration | Period | Analyzed | Benomyl | MBC | 5-HBC | 2-AB | 5-OH-2-AB |
| rat | Gardiner *et al.*, 1974 | oral | 72 hrs | urine | <5[a] | <5[a] | ~75 | | |
| dog | Gardiner *et al.*, 1974 | oral | 72 hrs | feces | - | ~70 | ~10 | | |
| mouse | Douch, 1973 | oral/IP | 96 hrs | urine | ND[b] | 30 | 8 | 12 | 5 |
| | | | | feces | ND | 15 | 9 | 8 | 5 |
| rabbit | Douch, 1973 | oral | 96 hrs | urine | ND | 23 | 11 | 11 | 10 |
| | | | | feces | ND | 4 | 8 | 12 | 4 |
| sheep | Douch, 1973 | oral | 96 hrs | urine | ND | 19 | 11 | 24 | 3 |
| | | | | feces | ND | 4 | 8 | 12 | 4 |
| rat | Belasco *et al.*, 1981 | dermal | 10 hrs | urine | - | "lesser" | "major" | | |
| rat | Belasco *et al.*, 1981 | IV | 6 hrs | urine | - | | 84-108 | | |

Melher, WH&S, 1991

[a] The dose recovered from each of the samples was less than 5%.
[b] ND = none detected; '-' symbol is used when data are not presented.

## OCCUPATIONAL EXPOSURE

A review of the available toxicological data by the Medical Toxicology Branch has indicated that an occupational risk for tumors may exist for workers experiencing chronic exposure to benomyl. An estimate of the chronic exposure for workers handling Benlate® can be derived from studies that observe the exposure from one day's work. From this single day exposure an absorbed daily dosage (ADD) can be estimated with the dermal absorption rate and a standardized body weight. If the number of days per year a worker handles a specific pesticide can be estimated, then the average annual daily dosage (AADD) and a lifetime average daily dosage (LADD) can be calculated. Since field workers have potentially longer work seasons that involve exposure to benomyl, the oncogenic risk from working in Benlate® treated crops should be derived from the average daily exposure for the work season for the purpose of deriving the AADD and LADD.

### I. APPLICATION:

The data available for evaluating the occupational exposure to benomyl is very limited. A data search of the Pesticide Registration Library on December 27, 1996 yielded only one study that monitored the exposure to benomyl from applying Benlate® to currently registered crops. The study by Everhart and Holt (1982) observed the exposure to benomyl for workers mixing and loading Benlate® for aerial applicators. Surgical gauze pads were used to observe the dermal exposure to the forearms, face, back and chest. Cotton gloves were used to detect exposure to the hands. The other body regions, thighs, legs and portions of the back and chest were considered protected by work clothing and exposure was not monitored. Ten replicates of the mixing/loading work task, lasting 1.5-5 minutes each, were observed. The composite dermal exposure estimated from the pads worn by each worker was calculated using a body surface area of 2,940 $cm^2$. The standardized body surface area for a 75.9 kg male worker is 19,400 $cm^2$ (Thongsinthusak *et al*., 1993). Pesticides, even in the wettable powder formulation, have the ability to penetrate work clothing. The standard protection value used by the Worker Health and Safety Branch for work clothing is 90% with 10% penetration (Thongsinthusak *et al*., 1993). The study is deficient in that the replicates were too short in duration and the patch monitoring did not represent several large body areas.

Exposure information is available in the Position Document 4 for Benomyl/Thiophanate-Methyl (U.S EPA, 1982). However, most of this information is derived from exposure data of other chemicals. The summaries are very brief with no details of the studies themselves other than the observed values. Without any background information on the surrogate studies used to derive the exposure estimates, it is not possible to evaluate the quality of the surrogate data.

The available data for benomyl is too limited in scope to be useful for estimating the occupational exposure from applying Benlate®. The Pesticide Handlers Exposure Database (PHED, 1995) was used to derive estimates of the exposure to benomyl for the various application methods. As a database composed of the results from studies which did not follow a standardized protocol, PHED has limitations to it's use as a surrogate database.

The PHED database was constructed as a summary of the exposure data from many studies, each with a different minimum detection level (MDL) for the analytical method used to detect residues in the sampling media. And since the detection of dermal exposure to the body regions was not standardized, some studies observed exposure to only selected body regions such as the hands, arms and face, with the other body regions considered 100% protected from exposure by work clothing. As a consequence the subsets derived from the database for dermal exposure have different number of observations (n) for each of the body regions.

The calculation of a standard deviation for the mean dermal exposure rate for the whole body is therefore not appropriate because the mean rate was derived as the sum of the mean rates for each body region which were derived from various numbers of observations (replicates). Although confidence intervals were provided for the derived mean dermal and inhalation rates, they may not represent an accurate expression of their variability. The physical properties of each pesticide were not included in the selection criteria for the database. As a consequence, the surrogate data derived for a specific pesticide can not be subsetted on the basis of similar physical properties such as vapor pressure, etc. Despite these limitations, PHED was used to derive data subsets that estimate the occupational exposure to benomyl for work tasks related to the application of Benlate® SP Fungicide.

The occupational exposure incurred for workers mixing and loading benomyl formulated in water soluble packets was estimated from a subset generated with the following selection criteria. The criteria for the minimum number of lbs. a.i. handled (> 10 lbs.) was included to exclude replicates from studies that may have observed exposure for home gardeners and residential pest control operators, and to exclude unrepresentatively short replicates.

| **Parameter** | **Comments** |
|---|---|
| Dermal grade-uncovered | All grades of studies A-E to maximize the number of replicates |
| Dermal grade-covered | All grades of studies A-E to maximize the number of replicates |
| Hand grade | All grades of studies A-E to maximize the number of replicates |
| Formulation-solid type | Wettable powder |
| Study location | Outdoor |
| Mixing procedure | Open |
| Total lbs. a.i. applied | Greater than 10.0 |
| Exposure units | μg/pound of a.i. handled |
| Inhalation rate | 25 L/min (PHED default) |
| Exposure | Combined dermal/inhalation |
| Head patches | Used actual and estimated head patches |
| Normal work clothing | Long pants, long-sleeved shirt, rubber gloves |

A summary of the exposure data generated from PHED for this subset is listed in Appendix A. The following mean (arithmetic) rates of exposure per pound of a.i. mixed and loaded were computed from the subset when the workers wore long pants, long-sleeved shirt and gloves: 359 μg of dermal exposure and 69.2 μg of inhalation exposure per pound of a.i. applied. Under federal WPS, mixer/loaders handling a category III pesticide with a closed system need only wear work clothing, shoes and socks without gloves or a respirator. A survey of exposure studies indicates for mixer/loaders, the exposure to the hands can account for 50% of the total dermal exposure or 179.5 μg/lb of a.i. handled, even when chemical resistant gloves are worn (Maddy *et al.,* 1984). If this value represents approximately 10% of the exposure to the hands when a 90% protection factor for rubber gloves is used (Thongsinthusak *et al.,* 1993), then the estimated exposure rate to the hands when gloves are not worn is 1795 µg/lb of a.i. handled (If 0.10 x = 179.5 µg/lb. a.i. handled, then x = 1795 µg/lb. a.i. handled). The estimated dermal exposure rate when the handlers wear only work clothing, shoes and socks is 1975 µg/lb of a.i. handled (1795 µg+ 179.5 µg/lb. a.i. handled).

The dermal and inhalation exposure values were then reduced by 95% to account for the protection provided by mixing and loading with a closed system (Thongsinthusak *et al.*, 1993). The estimated dermal and inhalation exposure incurred from mixing and loading benomyl formulated in water soluble packets are listed in Table II.

An estimate of the exposure incurred from applying benomyl with various types of application equipment was also derived from the PHED data base. One unique subset was generated for each of the listed work tasks with the following set of common selection criteria.

| **Parameter** | **Comments** |
|---|---|
| Dermal grade-uncovered | All grades of studies A-E to maximize the number of replicates |
| Dermal grade-covered | All grades of studies A-E to maximize the number of replicates |
| Hand grade | All grades of studies A-E to maximize the number of replicates |
| Formulation-liquid | Emulsifiable concentrate or aqueous suspension or solution |
| Study location | Outdoor |
| Total lbs. a.i. applied | Greater than 10 |
| Exposure units | µg/pound of a.i. handled |
| Inhalation rate | 25 L/min (PHED default) |
| Exposure | Combined dermal/inhalation |
| Head patches | Used actual and estimated head patches |
| Normal work clothing | Long pants, long-sleeved shirt, rubber gloves |

In addition each subset included one of the following parameters: orchard air blast equal to open cab; pilot-fixed-wing aerial equal to cockpit with window closed; and ground boom- ground boom tractor equal to open cab. The PHED exposure assessment was derived with the workers wearing long pants, long-sleeved shirt and gloves with the exception of the pilot who was not required to wear gloves while in the plane. The following mean rates of exposure per pound of a.i. applied were computed from the subsets: orchard air blast-204 µg of dermal exposure and 5.46 µg of inhalation exposure (Appendix B); pilot-11.9 µg of dermal exposure and 0.12 µg of inhalation exposure (Appendix C); and ground boom-135 µg of dermal exposure and 4.08 µg of inhalation exposure (Appendix D). The dermal exposure values for the arms, back, chest, head (only 50% of the value because rain hat does not protect the whole head) and legs of the orchard air blast or ground boom applicators were then reduced by 95% to account for the protection provided by the full body chemical resistant clothing (Thongsinthusak *et al.*, 1993). Inhalation exposure for the air blast and ground boom applicators was also reduced by 90% to account for the protection provided by the dust/mist filtering respirator required by the label (NIOSH, 1987). The estimates of the dermal and inhalation exposure from applying benomyl with various types of equipment are listed in Table II.

An estimate of the exposure incurred by flaggers assisting in the aerial application of benomyl with various types of aircraft was also derived from the PHED data base. One unique subset was generated for the flagger work task with the following set of selection criteria.

| Parameter | Comments |
|---|---|
| Dermal grade-uncovered | All grades of studies A-E to maximize the number of replicates |
| Dermal grade-covered | All grades of studies A-E to maximize the number of replicates |
| Hand grade | All grades of studies A-E to maximize the number of replicates |
| Application method | Aerial: fixed wing or rotary wing |
| Total lb a.i. flagged | Equal to or greater than 10 |
| Exposure units | µg/pound of a.i. handled |
| Inhalation rate | 25 L/min (PHED default) |
| Exposure | Combined dermal/inhalation |
| Head patches | Used actual and estimated head patches |
| Normal work clothing | Long pants, long-sleeved shirt |

A summary of the exposure data generated from PHED for this subset is listed in Appendix E. The following mean (arithmetic) rates of exposure per pound of a.i. flagged were computed from the subset when the worker wore long pants and a long-sleeved shirt: 73.6 µg of dermal exposure and 0.65 µg of inhalation exposure per pound of a.i. applied. The current Benlate® SP Fungicide label requires human flaggers to work from an enclosed cab. The dermal and inhalation exposure values were reduced by 90% to account for the protection provided by an enclosed cab without positive pressure or an air filtering system (Thongsinthusak *et al.*, 1993). Under federal WPS, workers flagging from an enclosed cab with a category III pesticide, need only wear work clothing, shoes and socks, and any respirator required by the handling work task. Since handlers are required to wear a dust/mist filtering respirator, the inhalation exposure component was reduced an additional 90% (Thongsinthusak *et al.*, 1993). The estimated dermal and inhalation exposure incurred by flaggers assisting in aerial applications of benomyl are listed in Table II.

## TABLE II Estimated Daily Dermal and Inhalation Exposure From Handling Benomyl in Water Soluble Packaging

| Work Task | Estimated Lbs. of A.I. Handled per Workday[a] | Dermal Exposure per Workday[b] (μg/person/day) | Inhalation Exposure per Workday[b] (μg/person/day) |
|---|---|---|---|
| **Mix/Load** | | | |
| air blast: stone fruit | 40 | 3,952 | 138 |
| aerial: almonds | 165 | 16,294 | 571 |
| ground boom: strawberries | 10 | 988 | 34.6 |
| **Apply** | | | |
| air blast: stone fruit | 40 | 2,204 | 22.0 |
| pilot: almonds | 165 | 1,964 | 19.8 |
| ground boom: strawberries | 10 | 1,080 | 4.1 |
| **Mix/Load/Apply[c]** | | | |
| air blast: stone fruit | 40 | 6,156 | 160 |
| ground boom: strawberries | 10 | 2,068 | 38.7 |
| **Flag** | | | |
| almonds | 165 | 1,214 | 1.16 |

Haskell, WH&S, 1997

[a] Values are estimates for crops that represent the majority of benomyl use (DPR, 1996). The amount of a.i. handled was derived from applying benomyl at the maximum label rate for the listed crops with the following volumes of water per acre: stone fruit-125 gallons; almonds-20-30 gallons and strawberries-200 gallons. The following estimated acres treated per day represent a full workday for the indicated application method: orchard air blast-40; fixed wing aircraft-220 and ground boom in strawberries-20 (Haskell, 1998).

[b] The following average exposure rates per pound of a.i. handled were used when workers mix, load and apply a pesticide formulated in a water soluble packet: a) mixing and loading - 98.8 ug of dermal and 3.46 ug of inhalation exposure; b) air blast application- 55.1 μg of dermal and 0.55 μg of inhalation exposure; c) ground boom application-108 μg of dermal and 0.41 μg of inhalation and d) aerial (fixed wing) application-11.9 μg of dermal and 0.12 μg of inhalation exposure. The estimated average rate of exposure for workers flagging an aerial application in almonds was 7.36 μg of dermal exposure and 0.007 μg of inhalation exposure per pound of a.i. applied by aircraft. See previous section for methodology. The dermal and inhalation exposure values were derived by multiplying the pounds handled per workday by the appropriate exposure rate.

[c] The dermal and inhalation exposure values were derived as the sum of the exposures from mixing/loading and applying benomyl for the listed application method and crop.

II. WORKING IN TREATED CROPS: STRAWBERRIES:

The Benlate® SP Fungicide label permits a maximum of 2.5 lbs. of a.i. to be applied on strawberries per growing season. The recommended usage is to apply 0.5 lb a.i. initially followed by 0.25 lb a.i. applications every 10-14 days for a theoretical maximum of nine applications per season. The 1992 crop of approximately 23,420 acres (University of California, 1994a) was treated with 11,442 lbs. of a.i. indicating an average of one application was made per season at the maximum label rate (DPR, 1994c). However, queries of the 1992 Pesticide Use Report data base with the PC-PUR program (PC-PUR, 1993) indicate the use of benomyl on strawberries varies according to the district and time of the season. The usage of benomyl on strawberries is limited in part by the problems inherent with it's use. Resistance to some of the labeled diseases, anthracnose and common leaf spot, has been observed in the field (University of California, 1994a). Benomyl is no longer labeled for the control of Grey mold (Botrytis) on strawberries. The current label recommends the use on strawberries only in combination with other labeled non-benzimidazole fungicides to slow the development of resistance. Benomyl is reportedly moderately toxic to the predators and parasites utilized in IPM programs on strawberries (University of California, 1994a). The desire to maintain predator and parasite populations during critical times of the season when the buildup of pest populations can occur may curtail the use of benomyl.

The most intensive use of benomyl on strawberries during the 1992 harvest season occurred in Orange County. A crop of 1731 acres received an average of three treatments with most of the applications taking place from January through March (DPR, 1994c; PC-PUR program, 1993). The harvest season for winter plantings starts in late January-early February and lasts for approximately four months, finishing in late May (The Pink Sheet, 1996). Averaging six workdays per week with a few extra days off for bad weather, the harvest season would last approximately 100 days. For the purposes of estimating the occupational exposure to benomyl for strawberry harvesters, exposure was estimated when three consecutive applications were made 14 days apart as recommended by the Benlate® SP Fungicide label. With a half-life of approximately 7 days, less than 2% of the initial deposition would be expected to remain 42 days after the final Benlate® SP Fungicide application (Mc Nally, 1990). The estimated maximum number of workdays during the harvest season that exposure to benomyl would be expected to occur would be 28 days preceeding the third sequential Benlate® application plus 42 days after the final application. From this total of 70 possible workdays, 10 days were subtracted to account for no harvesting on most Sundays and during bad weather.

An estimate of the dermal exposure can be made if the dislodgeable foliar residues (DFR) at the time of harvest are known and a transfer factor (dermal exposure per worker in μg/hour divided by the DFR) can be estimated for a particular work activity. The transfer factor is an estimate of the leaf surface of the crop contacted per hour while performing the work activity.

The deposition and degradation of benomyl and MBC on the leaf surfaces of strawberries was studied by Mc Nally (1990). Three strawberry fields in Florida were sprayed at the maximum rate of 0.5 lb a.i. per acre at seven day intervals for a total of seven applications. Leaf punch samples were taken prior to the first and seventh applications, immediately following each of the seven applications, and at 1, 2, 4, 7, and 14 days after the seventh application. The samples were washed with a detergent solution to dislodge the benomyl residues and then heated to convert the benomyl to it's principle metabolite, MBC. The samples were frozen and stored until analysis with liquid chromatography. The results were expressed as the sum of the residues of benomyl and carbendazim detected.

The residue data indicated there was little accumulation of benomyl after each successive Benlate® SP Fungicide application. The half-life was estimated as seven days. A linear regression analysis of the DFR observed after the seventh application yielded the following equation: $y = -0.38967 + (-0.10751x)$ where y = natural log of $\mu g/cm^2$ and x = days (Appendix F). This equation was used to estimate the average DFR present ($0.16\ \mu g/cm^2$) over a 42 day period after the last application. This value represents the average DFR present while the benomyl residues degrade through approximately six half-lives when less than 2% of the initial residues would be expected to still be present. The $0.16\ \mu g/cm^2$ value was then used to estimate the average daily exposure for the strawberry harvesters during the Benlate® SP Fungicide use season. A transfer factor of 1,776 $cm^2$ of foliage contacted per hour was derived from an exposure study that observed the exposure of strawberry harvesters to captan (Edmiston *et al.,* 1990). The product of the transfer factor and the average DFR yielded an estimated 284 µg of dermal exposure per hour of work or 2.27 mg per eight-hour workday.

Although inhalation exposure to benomyl was not estimated for the strawberry harvesters, it is not likely to be a significant route of exposure. In the strawberry harvester exposure study by Holt *et al.* (1979), the respiratory component accounted for less than 0.1% of the total exposure.

The exposure to benomyl for farm workers harvesting Benlate®-treated strawberries for a single workday was observed in the study by Holt *et al.* (1979). The potential dermal and inhalation exposure was monitored for three adult females picking strawberries for two hours approximately 24 hours after a maximum label treatment of 1.0 lb of Benlate® SP Fungicide per acre. Exposure data from this study would be appropriate to use for evaluating the risk for an acute exposure from one workday. However, since the toxicological concern for benomyl arises from chronic exposure, the observations from this study are not appropriate for evaluating risk. An AADD derived from this exposure data would over-estimate the chronic occupational exposure because the value for the AADD was derived with the assumption that every harvest day of the season after the second application (60 days), was preceded with a Benlate® SP Fungicide application.

II. WORKING IN TREATED CROPS: GRAPES

The Benlate® SP Fungicide label permits a maximum of 3.0 lbs. of a.i. to be applied on grapes per growing season with 0.50-0.75 lb a.i. applied per application every 14 days for the control of Botrytis Bunch Rot. The Pesticide Use Report indicates that 33,986 acres of the 642,450 acres of grapes grown in California were treated during the 1992 growing season (DPR, 1994c). These applications were made primarily in April-June in the southern San Joaquin Valley which coincides with bloom through early berry set for grapes. The Grape Pest Management guidelines recommend leaf canopy management or a single application of a fungicide during the bloom and early fruit set to control Botrytis Bunch Rot (University of California, 1994b). Workers can start the cultural practices of bunch thinning and/or leaf removal in grapes approximately 14 days after berry set (Peacock, 1993). The dermal exposure to benomyl from performing this work activity can be estimated as the product of the DFR present when the work activity is performed and a transfer factor that is specific for the work activity. A transfer factor of 9,000 $cm^2$ (table grapes) or 11,000 $cm^2$ (wine grapes) of foliage contacted per hour of work was used to estimate the actual dermal exposure for these cultural practices in grapes (Welsh *et al.*, 1993).

The deposition and degradation of benomyl on the leaf surfaces of grapes was studied by Powley (1989). Three sites in the San Joaquin Valley were treated with a single application of Benlate® DF Fungicide at the maximum label rate of 0.75 lb a.i. per acre. Leaf punch samples were taken prior to the application and at 1, 4, 7, 14, and 21 days after the application at each site. The samples were washed with a detergent solution to dislodge the benomyl residues and then heated to convert the benomyl to it's principle metabolite, carbendazim. The samples were stored frozen until analysis with liquid chromatography. The results were expressed as the sum of the residues of benomyl and carbendazim detected. A linear regression analysis of the average DFR observed yielded the following equation: y = -0.10276 + (-0.03974 days) where y = natural log of $\mu g/cm^2$ and x = days (Appendix G). This equation was used to estimate the average DFR present (0.36 $\mu g/cm^2$) over a 21 day work period starting 14 days after the Benlate® DF Fungicide application. With an average DFR of 0.36 $\mu g/cm^2$ present during the work period, farm workers thinning bunches and/or pulling leaves in table grapes could experience a dermal exposure of 3.24 mg (9,000 $cm^2$ X 0.36 $\mu g/cm^2$) per hour or 25.9 mg during an eight-hour workday. For wine grapes, the estimated daily dermal exposure was 31.7 mg (11,000 X 0.36 $\mu g/cm^2$ X 8 hours) per workday.

Farm workers harvesting other crops treated with benomyl can also be exposed to benomyl. Attachment One has derived estimates of the dermal exposure to workers for other hand-harvested crops that are sometimes treated with benomyl. The values in Table I of Attachment One support the observation that work tasks related to cultural practices in grapes can result in some of the greatest occupational exposures to benomyl.

The amount of exposure via the inhalation route was considered insignificant for hand labor work tasks performed in benomyl treated crops. A study by Wolfe (1976) surveyed the results from many exposure studies for workers mixing/loading and applying different pesticides with a variety of formulations. As a part of the total exposure for the worker, the inhalation component accounted for less than 1% (mean value) with a range of 0.1-3.1% for the studies reviewed. As farm workers are exposed to diluted spray residues after an application, their exposure is expected to be less.

## III. NON-OCCUPATIONAL EXPOSURE FROM HOME GARDEN USES

The exposure of home owners applying home garden products that contain benomyl was estimated in earlier drafts of this exposure assessment utilizing two studies of urban applicators applying carbaryl (Gold *et al*., 1982; Leavitt *et al.*, 1981). However, this section has been deleted from the current draft because this use pattern is expected to be discontinued in the next year or so. The trend of benomyl use in the home-garden market has been declining for several years. In the early 90's several companies had home-garden products containing benomyl. In 1996 only the Acme Division of PBI Gordon Corp. and the Green Light Company had benomyl products registered in California. Now, in 1997, only the Green Light Company's Green Light Systemic Fungicide with Benomyl, is registered in California. The product manager at the Green Light

Company has indicated the product is currently registered in California only to cover the product that may still be in the channels of trade. Du Pont Chemical is no longer selling technical benomyl that can be used for formulating home-garden products. And the Green Light Company is not manufacturing the product and does not have any left in storage. It seems appropriate to conclude that the home-garden use of benomyl will not exist in a year or two. An exposure assessment is not necessary for this use pattern.

**Table III Lifetime Average Daily Dosage For Work Tasks That Involve Exposure to Benomyl**

| Work Task | Daily Dermal Exposure (µg/person/day) | Inhalation Exposure (µg/person/day) | Absorbed Daily Dosage[a] (µg/kg/day) | Average Annual Daily Dosage[b] (µg/kg/day) | Lifetime Average Daily Dosage[c] (µg/kg/day) |
|---|---|---|---|---|---|
| **Mix/Load** | | | | | |
| air blast-stone fruit | 3,952 | 138 | 6.12 | 0.10 | 0.05 |
| aerial-almonds | 16,294 | 571 | 25.2 | 1.04 | 0.56 |
| ground-strawberries | 988 | 34.6 | 1.53 | 0.12 | 0.06 |
| **Apply** | | | | | |
| air blast-stone fruit | 2,204 | 22.0 | 3.05 | 0.05 | 0.03 |
| aerial almonds | 1,964 | 19.8 | 2.72 | 0.11 | 0.06 |
| ground-strawberries | 1,080 | 4.1 | 1.45 | 0.12 | 0.06 |
| **Mix/Load/Apply** | | | | | |
| air blast-stone fruit | 6,156 | 160 | 9.17 | 0.15 | 0.08 |
| ground-strawberries | 2,068 | 38.7 | 2.98 | 0.24 | 0.13 |
| **Flag** | 1,214 | 1.16 | 1.61 | 0.07 | 0.04 |
| **Harvest** | | | | | |
| strawberries | 2,272 | not monitored | 3.69 | 0.61 | 0.33 |
| **Field work-** | | | | | |
| shoot thinning, pulling leaves | | | | | |
| (table grapes) | 25,900 | not monitored | 42.1 | 2.42 | 1.29 |
| (wine grapes) | 31,700 | not monitored | 51.6 | 2.97 | 1.58 |

Haskell, WH&S, 1995

[a] The Average Daily Dosage (ADD) was calculated with a dermal absorption rate of 10%. Inhalation absorption was considered as 50% uptake and 100% absorption (Raabe, 1988). Since the PHED exposure studies were conducted with primarily male workers, the body weight of the workers was assumed to be 75.9 kg (Thongsinthusak *et al.*, 1993). However, since farm workers can be male or female, a body weight of 61.5 kg was used to calculate the ADD for field work.

[b] The Average Annual Daily Dosage (AADD) was calculated by multiplying the ADD by the estimated number of annual eight-hour workdays the task was performed and then dividing the product by 365. The annual number of workdays were estimated for the following work tasks:

1. air blast application in stone fruits-6 (Edwards, 1992).
2. aerial application in almonds-15 (50% of 30-day application season; University of California, 1985).
3. ground boom application in strawberries-29 (Haskell, 1998).
4. harvesting strawberries-60 (see text on page 13).
5. pulling grape leaves-21 (Smith, 1989).

[c] The Lifetime Average Daily Dose (LADD) was calculated with the workers being exposed for 40 years with a life expectancy of 75 years (Thongsinthusak *et al.*, 1993).

## Appraisal of Factors Influencing Exposure Assessment

There are several factors used to estimate occupational exposure and to calculate the Absorbed Daily Dosage that are conservative (tendency to overestimate the value of concern) in nature. These factors are real, but are typically buried in the calculations and not acknowledged. This section is an attempt to put these experimental factors in perspective with what is expected to happen in the work place.

A. Occupational exposure assessment

A common practice in pesticide exposure assessment is to measure the exposure that occurs during a few replicates of the work task and then normalize it to estimate the exposure from an eight-hour workday. Observations made in studies that varied the length of time of the replicates used to measure the exposure to pesticides observed that initially pesticide residue acquisition is at a higher rate (Spencer *et al.*, 1991; Franklin *et al.*, 1981). This higher rate is then followed by an acquisition rate that is lower and remains relatively constant for the duration of the workday. Results taken from replicates that only make observations during this initial period of greater residue acquisition will overestimate the residues acquired over an eight-hour workday. In turn, the Absorbed Daily Dosage calculated from this workday exposure will overestimate the daily dosage used to calculate the risk for an acute adverse health effect.

B. Calculations for the Absorbed Daily Dosage

To derive the Absorbed Daily Dosage, an estimate of the percent of the dermal exposure that will become bioavailable, is needed. For benomyl, this value was obtained from a rat study. Rats are used because they are relatively cheap and most of the toxicology is done with them. Also many companies have an aversion to using humans for the determination of dermal absorption, even though they are the species of choice. However, rats typically overestimate human dermal absorption by two to ten fold. This has been demonstrated in approximately a dozen different compounds tested in rats and man (Wester and Maibach, 1977, 1993; Shah and Guthrie, 1983; Sanborn, 1994; Thongsinthusak, 1994).

The deposition of pesticide residues from occupational exposure is generally uneven over the body and some regions (e.g., the hands) can constitute up to 50% of the total dermal exposure (Maddy *et al.*, 1984). The rates of dermal absorption observed in animal studies were generally inversely proportional to the amount of deposition (Wester and Maibach, 1993). However, the hands are assumed to have the same rate of absorption as the other body regions thus typically overestimating the absorbed dose. Also bioavailability of a dermal dose declines with increasing concentration (Maibach and Feldman, 1974; Shah *et al.*, 1987 ).

The toxic effects of pesticides are typically observed in animal studies in which the animals are dosed orally (in food or by gavage) with the pesticide in incremental doses until an effect is observed. The dose is absorbed in the gastrointestinal tract and the adverse effect occurs to the target organs only when the plasma level reaches a critical concentration. The no observed effect level (NOEL) is an estimate of the maximum dosage an organism can tolerate without manifesting the adverse effect. The NOEL divided by a factor of 10 or 100 provides an estimate of the maximum occupational exposure conventionally considered safe. Occupational exposure to pesticides occurs primarily via the dermal route. However, dermal acquisition occurs over the entire workday and the rate of dermal absorption is slower than the oral absorption rate. A dermal dose acquired over the entire workday produces peak plasma levels at much lower levels than those from a bolus or oral feeding dosage acquired by animals in seconds to minutes (Auton *et al.*, 1993). Because the effect is highly dependent on plasma level, the net result of assuming instantaneous dermal dose acquisition and absorption is an overestimate of peak plasma concentration compared to the oral route for the same absorbed dose. To conclude that an dermal dose will have a similar toxic effect at the same lowest observed effect level (LOEL) for an orally administered dose is very conservative and typically overestimates peak plasma levels by several fold (Nolan *et al.*, 1984).

C. Conclusion

These factors are operating in the occupational exposure assessment for benomyl and as they are multiplicative, the result is significant overestimates of the Absorbed Daily Dosage for the various work tasks. A realistic upper bound estimate of exposure under normal use conditions is adequately represented by the mean estimates of exposure when all the unacknowledged conservatism built into the estimate of exposure via the dermal route are considered.

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# APPENDIX A

SUMMARY STATISTICS FOR CALCULATED DERMAL AND INHALATION EXPOSURES FOR MIXER\LOADER

**Exposure Scenario: Long pants, long sleeves, rubber gloves**

| PATCH | DISTRIBUTION | MICROGRAMS PER LB AI SPRAYED | | | | |
|---|---|---|---|---|---|---|
| LOCATION | TYPE | Median | Mean | Coef of Var | Geo, Mean | Obs |
| Head (all) | Normal | 50.115 | 61.5956 | 88.6237 | 36.0571 | 32 |
| Neck-front | Lognormal | 12.9 | 43.3838 | 239.4894 | 11.3848 | 32 |
| Neck-back | Lognormal | 4.7355 | 29.5316 | 260.4705 | 4.3058 | 32 |
| Upper arms | Lognormal | 15.714 | 45.2591 | 142.1951 | 20.107 | 17 |
| Chest | Lognormal | 18.9925 | 57.7097 | 138.8205 | 27.4647 | 16 |
| Back | Lognormal | 18.9925 | 57.2881 | 140.2625 | 26.6824 | 16 |
| Forearms | Lognormal | 8.591 | 22.385 | 107.2115 | 13.6142 | 21 |
| Thighs | Lognormal | 9.55 | 14.3771 | 104.053 | 7.7258 | 11 |
| Lower legs | Lognormal | 4.76 | 6.9972 | 89.9374 | 5.1515 | 10 |
| Feet | ----- | ----- | ----- | ----- | ----- | ----- |
| Hands | Lognormal | 12.2678 | 20.4642 | 108.1352 | 11.407 | 20 |
| | | | | | | |
| TOTAL DERM: | 189.4388 | 156.6183 | 358.9914 | | 163.9003 | |
| INHALATION: | Lognormal | 6.8871 | 69.1863 | 196.0823 | 6.322 | 35 |
| COMBINED: | 195.7608 | 163.5054 | 428.1777 | | 170.2223 | |

95% Confidence Interval on Mean: DERMAL: (-2226.3104, 2944.2932)
95% Confidence Interval on Mean: INHALATION: (0.0291, 1374.1733)

Inhalation rate: 25 Liters/minute
Number of Records: 48
Data file: MIXER\LOADER Subset Name: WPMIXLOAD.MLOD

# APPENDIX B

SUMMARY STATISTICS FOR CALCULATED DERMAL AND INHALATION EXPOSURES FOR ORCHARD AIR-BLAST APPLICATOR

**Exposure Scenario: Long pants, long sleeves, rubber gloves**

| PATCH | DISTRIBUTION | MICROGRAMS PER LB AI SPRAYED | | | | |
|---|---|---|---|---|---|---|
| LOCATION | TYPE | Median | Mean | Coef of Var | Geo, Mean | Obs |
| Head (all) | Lognormal | 61.035 | 138.3778 | 121.2148 | 68.4161 | 18 |
| Neck-front | Lognormal | 7.9275 | 14.0633 | 116.8047 | 7.6855 | 18 |
| Neck-back | Lognormal | 11.9845 | 24.2251 | 136.3198 | 9.8301 | 18 |
| Upper arms | Lognormal | 0.873 | 1.067 | 79.6251 | 0.8179 | 15 |
| Chest | Lognormal | 1.065 | 3.4317 | 169.7584 | 1.5174 | 18 |
| Back | Lognormal | 1.065 | 2.2681 | 123.1427 | 1.355 | 18 |
| Forearms | Lognormal | 0.363 | 1.21 | 244.7355 | 0.4642 | 18 |
| Thighs | -------- | 0.000 | 0.000 | 0.000 | 0.000 | 0 |
| Lower legs | Lognormal | 0.952 | 1.1107 | 24.7412 | 1.0898 | 3 |
| Feet | Lognormal | 9.301 | 9.17 | 57.8702 | 7.9851 | 3 |
| Hands | Lognormal | 1.6273 | 8.9272 | 133.5256 | 3.4258 | 18 |
| TOTAL DERM: | 102.5869 | 96.1933 | 203.8509 | | 102.5869 | |
| INHALATION: | Lognormal | 4.7992 | 5.4592 | 77.2622 | 3.6497 | 18 |
| COMBINED: | 106.2366 | 100.9925 | 209.3101 | | 106.2366 | |

95% Confidence Interval on Mean: DERMAL: (-2320.4822, 2728.184)
95% Confidence Interval on Mean: INHALATION: (0.4876, 27.3185)

Inhalation rate: 25 Liters/minute
Number of Records: 18
Data file: APPLICATOR Subset Name: ORCHARD2.APPL

# APPENDIX C

SUMMARY STATISTICS FOR CALCULATED DERMAL AND INHALATION EXPOSURES FOR PILOT

**Exposure Scenario: Long pants, long sleeves, no gloves**

| PATCH LOCATION | DISTRIBUTION TYPE | MICROGRAMS PER LB AI SPRAYED Median | Mean | Coef of Var | Geo, Mean | Obs |
|---|---|---|---|---|---|---|
| Head (all) | Other | 0.13 | 0.4215 | 197.0344 | 0.2057 | 33 |
| Neck-front | Other | 0.015 | 0.0377 | 167.1088 | 0.0227 | 33 |
| Neck-back | Other | 0.011 | 0.0307 | 180.7818 | 0.0167 | 33 |
| Upper arms | Other | 0.291 | 0.3233 | 42.4374 | 0.3093 | 18 |
| Chest | Other | 0.355 | 0.355 | 0.000 | 0.355 | 19 |
| Back | Other | 0.355 | 0.355 | 0.000 | 0.355 | 19 |
| Forearms | Other | 0.121 | 0.1412 | 33.3569 | 0.1358 | 12 |
| Thighs | Other | 0.382 | 0.382 | 0.000 | 0.382 | 16 |
| Lower legs | Other | 0.238 | 0.2909 | 52.9048 | 0.2689 | 18 |
| Feet | Lognormal | 0.393 | 0.4803 | 88.8195 | 0.3311 | 12 |
| Hands | Lognormal | 2.025 | 9.0963 | 243.2637 | 1.8675 | 29 |
| | | | | | | |
| TOTAL DERM: | 4.0966 | 4.316 | 11.9139 | | 4.2497 | |
| INHALATION: | Lognormal | 0.0312 | 0.1213 | 205.2762 | 0.0338 | 21 |
| COMBINED: | 4.1304 | 4.3472 | 12.0352 | | 4.2835 | |

95% Confidence Interval on Mean: DERMAL: (-243.0333,  266.8611)
95% Confidence Interval on Mean: INHALATION: (0.0015,  0.7624)

Inhalation rate: 25 Liters/minute
Number of Records: 33
Data file: APPLICATOR                    Subset Name: AERIAL.APPL

# APPENDIX D

SUMMARY STATISTICS FOR CALCULATED DERMAL AND INHALATION EXPOSURES FOR GROUND BOOM APPLICATOR

**Exposure Scenario: Long pants, long sleeves, rubber gloves**

| PATCH LOCATION | DISTRIBUTION TYPE | Median | Mean | Coef of Var | Geo, Mean | Obs |
|---|---|---|---|---|---|---|
| | | MICROGRAMS PER LB AI SPRAYED | | | | |
| Head (all) | Lognormal | 2.21 | 9.841 | 209.7328 | 2.2874 | 60 |
| Neck-front | Lognormal | 0.255 | 0.8244 | 136.9238 | 0.2509 | 53 |
| Neck-back | Lognormal | 0.1925 | 0.9448 | 262.7223 | 0.1853 | 54 |
| Upper arms | Lognormal | 0.582 | 1.2368 | 112.5081 | 0.7686 | 16 |
| Chest | Lognormal | 2.13 | 6.0283 | 197.1601 | 2.0529 | 53 |
| Back | Lognormal | 2.13 | 7.3709 | 186.2066 | 2.225 | 38 |
| Forearms | Lognormal | 0.726 | 4.3664 | 266.982 | 0.847 | 35 |
| Thighs | Lognormal | 0.573 | 1.337 | 123.4405 | 0.8188 | 16 |
| Lower legs | Lognormal | 0.952 | 2.2277 | 138.6452 | 1.0661 | 25 |
| Feet | Lognormal | 1.048 | 20.3196 | 211.3742 | 1.9643 | 9 |
| Hands | Lognormal | 36.64 | 80.8191 | 125.2131 | 49.1592 | 11 |
| | | | | | | |
| TOTAL DERM: | 61.6255 | 47.4385 | 135.316 | | 61.6255 | |
| INHALATION: | Other | 1.2127 | 4.8012 | 182.7876 | 1.3293 | 66 |
| COMBINED: | 62.8382 | 48.6512 | 140.1172 | | 62.9548 | |

95% Confidence Interval on Mean: DERMAL: (-1971.4295, 2242.0615)
95% Confidence Interval on Mean: INHALATION: (0.0444, 39.7927)

Inhalation rate: 25 Liters/minute
Number of Records: 67
Data file: APPLICATOR Subset Name: GROUNDBOOM.APPL

# APPENDIX E

SUMMARY STATISTICS FOR CALCULATED DERMAL AND
INHALATION EXPOSURES FOR FLAGGER

**Exposure Scenario: Long pants, long sleeves, no gloves**

| PATCH LOCATION | DISTRIBUTION TYPE | MICROGRAMS PER LB AI SPRAYED Median | Mean | Coef of Var | Geo, Mean | Obs |
|---|---|---|---|---|---|---|
| Head (all) | Other | 1.235 | 46.1817 | 559.396 | 2.5595 | 82 |
| Neck-front | Other | 0.1425 | 1.1421 | 220.5324 | 0.2143 | 78 |
| Neck-back | Lognormal | 0.1485 | 1.9619 | 265.4468 | 0.213 | 78 |
| Upper arms | Other | 0.582 | 3.0482 | 214.1461 | 0.8204 | 40 |
| Chest | Other | 0.355 | 3.2457 | 224.9191 | 0.8911 | 49 |
| Back | Other | 0.355 | 3.8036 | 201.496 | 1.0168 | 49 |
| Forearms | Other | 0.1815 | 1.3252 | 204.9351 | 0.3489 | 42 |
| Thighs | Other | 0.764 | 3.4162 | 314.7474 | 1.036 | 35 |
| Lower legs | Other | 0.595 | 2.1486 | 307.0371 | 0.6956 | 36 |
| Feet | ------- | 0.000 | 0.0000 | 0.0000 | 0.0000 | 0 |
| Hands | Lognormal | 1.7176 | 7.327 | 155.2914 | 1.408 | 70 |

| | | | | | | |
|---|---|---|---|---|---|---|
| TOTAL DERM: | 5.831 | 6.0761 | 73.6002 | | 9.2036 | |
| INHALATION: | Other | 0.146 | 0.6492 | 193.13 | 0.1983 | 76 |
| COMBINED: | 5.977 | 6.2221 | 74.2494 | | 9.4019 | |

95% Confidence Interval on Mean: DERMAL: (-1705.7874, 1852.9878)
95% Confidence Interval on Mean: INHALATION: (0.0086, 4.5811)

Inhalation rate: 25 Liters/minute
Number of Records: 92
Data file: FLAGGER Subset Name: FLAGGER.BENOMYL

# APPENDIX F

## AVERAGE DISLODGEABLE FOLIAR RESIDUES OF BENOMYL DURING STRAWBERRY HARVEST SEASON

Linear regression of dislodgeable foliar residues (DFR) after three consecutive applications of Benlate on strawberries (Mc Nally, 1990)

| Days | DFR | Ln of DFR | Slope | Intercept | R^2 |
|---|---|---|---|---|---|
| 0.1 | 0.64 | -0.446287103 | -0.10751 | -0.38967 | -0.9834 |
| 1 | 0.54 | -0.616186139 | | | |
| 2 | 0.55 | -0.597837001 | | | |
| 4 | 0.52 | -0.653926467 | | | |
| 7 | 0.34 | -1.078809661 | | | |
| 14 | 0.14 | -1.966112856 | | | |

Ln(DFR) = -0.38967 - 0.10751 days
Half-life = 7 days
Peak harvest season, approximately 80 days

| Days After Third Application | Natural Log Value of DFR From Linear Regression | Calculated DFR in ug/cm2 |
|---|---|---|
| 0 | -0.3897 | 0.677 |
| 1 | -0.4972 | 0.608 |
| 2 | -0.6047 | 0.546 |
| 3 | -0.7122 | 0.491 |
| 4 | -0.8197 | 0.441 |
| 5 | -0.9272 | 0.396 |
| 6 | -1.0347 | 0.355 |
| 7 | -1.1422 | 0.319 |
| 8 | -1.2498 | 0.287 |
| 9 | -1.3573 | 0.257 |
| 10 | -1.4648 | 0.231 |
| 11 | -1.5723 | 0.208 |
| 12 | -1.6798 | 0.186 |
| 13 | -1.7873 | 0.167 |
| 14 | -1.8948 | 0.150 |
| 15 | -2.0023 | 0.135 |
| 16 | -2.1098 | 0.121 |
| 17 | -2.2173 | 0.109 |
| 18 | -2.3249 | 0.098 |
| 19 | -2.4324 | 0.088 |
| 20 | -2.5399 | 0.079 |
| 21 | -2.6474 | 0.071 |
| 22 | -2.7549 | 0.064 |
| 23 | -2.8624 | 0.057 |
| 24 | -2.9699 | 0.051 |

## APPENDIX F (cont)

AVERAGE DISLODGEABLE FOLIAR RESIDUES OF BENOMYL
DURING STRAWBERRY HARVEST SEASON

| Days After Third Application | Natural Log Value of DFR From Linear Regression | Calculated DFR in ug/cm2 |
|---|---|---|
| 25 | -3.0774 | 0.046 |
| 26 | -3.1849 | 0.041 |
| 27 | -3.2924 | 0.037 |
| 28 | -3.4000 | 0.033 |
| 29 | -3.5075 | 0.030 |
| 30 | -3.6150 | 0.027 |
| 31 | -3.7225 | 0.024 |
| 32 | -3.8300 | 0.022 |
| 33 | -3.9375 | 0.019 |
| 34 | -4.0450 | 0.018 |
| 35 | -4.1525 | 0.016 |
| 36 | -4.2600 | 0.014 |
| 37 | -4.3675 | 0.013 |
| 38 | -4.4751 | 0.011 |
| 39 | -4.5826 | 0.010 |
| 40 | -4.6901 | 0.009 |
| 41 | -4.7976 | 0.008 |
| 42 | -4.9051 | 0.007 |
| | Average DFR during harvest season | 0.157 |

# APPENDIX G

AVERAGE DISLODGEABLE FOLIAR RESIDUES OF BENOMYL ON GRAPES DURING MID SEASON CULTURAL PRACTICES

Linear regression of dislodgeable foliar residues (DFR) of benomyl after one maximum label treatment of Benlate on grapes
(Powley, 1989).

| Days | Average DFR for three treatment sites | Ln of DFR | slope | intercept | R^2 |
|---|---|---|---|---|---|
| 1 | 0.87 | -0.1393 | -0.03974 | -0.10276 | -0.99856 |
| 4 | 0.72 | -0.3285 | | | |
| 7 | 0.61 | -0.4943 | | | |
| 14 | 0.43 | -0.8440 | | | |
| 21 | 0.4 | -0.9163 | | | |

Ln (DFR) = -0.10276 - 0.03974 days
Half-life = 18 days
Length of work season for thinning bunches,
pulling leaves = 21 days

| Days After Application | Natural Log Value of DFR From Linear Regression | Calculated DFR in ug/cm2 |
|---|---|---|
| 14 | -0.6591 | 0.52 |
| 15 | -0.6989 | 0.50 |
| 16 | -0.7386 | 0.48 |
| 17 | -0.7783 | 0.46 |
| 18 | -0.8181 | 0.44 |
| 19 | -0.8578 | 0.42 |
| 20 | -0.8976 | 0.41 |
| 21 | -0.9373 | 0.39 |
| 22 | -0.9770 | 0.38 |
| 23 | -1.0168 | 0.36 |
| 24 | -1.0565 | 0.35 |
| 25 | -1.0963 | 0.33 |
| 26 | -1.1360 | 0.32 |
| 27 | -1.1757 | 0.31 |
| 28 | -1.2155 | 0.30 |
| 29 | -1.2552 | 0.29 |
| 30 | -1.2950 | 0.27 |
| 31 | -1.3347 | 0.26 |
| 32 | -1.3744 | 0.25 |
| 33 | -1.4142 | 0.24 |
| 34 | -1.4539 | 0.23 |
| | Average DFR during mid-season cultural practices | 0.36 |

## ATTACHMENT ONE

Farm workers working in table grapes are expected to experience some of the greatest exposures to benomyl. An estimate of their occupational exposure was included in the text and Table III of the exposure assessment for benomyl. Estimates of the dermal exposure incurred from harvesting other benomyl-treated crops are listed in the following table.

### Table I Estimated Dermal Exposure to Farm Workers from Hand Harvesting Various Crops Treated with Benomyl

| Crops[a] | Maximum Label Rate (lbs. a.i./acre) | Pre-harvest Interval (PHI) (days) | DFR at PHI[b] ($\mu g/cm^2$) | Transfer Factor[c] ($cm^2$/hour) | Dermal Exposure[d] (mg/person/day) |
|---|---|---|---|---|---|
| celery | 0.25 | 7 | 0.17 | 1776 | 2.42 |
| nectarines | 1.0 | 3 | 0.91 | 4023 | 29.3 |
| peaches | 1.0 | 3 | 0.91 | 4023 | 29.3 |

Haskell, WH&S, 1995

[a] Hand harvested crops that were reported treated with more than 10,000 lbs. of benomyl during the 1992 growing season (DPR, 1994).

[b] Dislodgeable foliar residues (DFR) for various crops.
1. celery-surrogate DFR data from benomyl application on strawberries 7 days after the treatment, then divided by 2 to account for lower maximum label rate (Mc Nally, 1990).
2. nectarines and peaches-surrogate DFR data from azinphos-methyl application on plums; DFR value at one hour post application = 1.81 $\mu g/cm^2$ (mean value from 18 replications) (Spencer *et al.*, 1988). Multiplied by 0.67 to account for the lower application rate for benomyl and then reduced by 25% to account for the approximate degradation for a three day pre-harvest interval (7 day half-life-Mc Nally, 1990).

[c] Transfer factor ($cm^2$ of foliage contacted/hour) $= \dfrac{\text{Dermal Exposure } (\mu g/\text{hour})}{\text{Dislodgeable Foliar Residue } (\mu g/cm^2)}$
1. 1776 $cm^2$/hour for vegetable row crop (Edmiston *et al.*, 1990).
2. 4023 $cm^2$/hour for tree crops (see Table I of Attachment Two).

[d] Dermal exposure = DFR x Transfer Factor x 8 (exposure hours per day) ÷ 1,000 µg/mg.

## Table II Lifetime Average Daily Dosage For Harvest Tasks That Involve Exposure to Benomyl

| Crops | Daily Dermal Exposure[a] (mg/person/day) | Inhalation Exposure (mg/person/day) | Absorbed Daily Dosage[b] (μg/kg/day) | Average Annual Daily Dosage[c] (μg/kg/day) | Lifetime Average Daily Dosage[d] (μg/kg/day) |
|---|---|---|---|---|---|
| Celery | 2.42 | NA | 3.94 | 0.90 | 0.48 |
| Nectarines | 29.3 | NA | 47.6 | 1.44 | 0.77 |
| Peaches | 29.3 | NA | 47.6 | 0.78 | 0.42 |

Haskell, WH&S, 1996

NA = The amount of exposure via the inhalation route was considered insignificant for a pesticide with a low vapor pressure. A study by Wolfe (1976) surveyed the results from many exposure studies for workers mixing/loading and applying different pesticides with a variety of formulations. As a part of the total exposure for the worker, the inhalation component accounted for less than 1% (mean value) with a range of 0.1-3.1 % for the studies reviewed.

[a] Values taken from column six of Table I.

[b] The Average Daily Dosage (ADD) was calculated with a dermal absorption rate of 10%. Since farm workers can be male or female, a body weight of 61.5 kg was used to calculate the ADD for field work.

[c] The Average Annual Daily Dosage (AADD) was calculated by multiplying the ADD by the estimated number of annual eight-hour workdays that exposure to benomyl occurred and then dividing the product by 365. The annual number of workdays were estimated for the following work tasks:

1. harvesting celery (central coast)- June-December, 143 days (USDA, 1992).
2. harvesting nectarines (southern San Joaquin Valley)- mid-May through mid-September 102 days (Calif., 1990).
3. harvesting peaches-southern San Joaquin Valley, mid-May through mid-September 102 days (Calif.,1990).

Exposure days were then estimated by multiplying the number of days in the harvest season by the percentage of the crop treated during the harvest season in a particular county.

1. celery (Monterey County) 143 days X 0.58 = 83 exposure days per season (Monterey County, 1992; DPR, 1994).
2. nectarines (Tulare County) 102 days X 0.11 = 11 exposure days per season (Calif. Fruit & Nut Acreage, 1992; DPR, 1994).
3. peaches (Tulare County) 102 days X 0.06 = 6 days (Calif. Fruit & Nut Acreage, 1992; DPR, 1994).

[d] The Lifetime Average Daily Dose (LADD) was calculated with the workers being exposed for 40 years with a life expectancy of 75 years (Thongsinthusak *et al.*, 1993).

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## ATTACHMENT TWO

### Table I Estimation of a Generic Transfer Factor For Tree Crop Harvesters From Dermal and Dislodgeable Foliar Residue Data

| Pesticide and year applied(a) | Crop and application site | No. of days post application(b) | Observed DFR ($\mu g/cm^2$)(c) | No. of workers Monitored(d) | Mean dermal exposure per harvester (mg/8 hour workday) | Transfer factor for harvesters ($cm^2$/hour)(e) | Total foliage contacted by all harvesters in crew ($cm^2$/hour)(f) |
|---|---|---|---|---|---|---|---|
| Azinphos-methyl, 1989 (1) | Peaches Sutter County | 32 | 0.66 | ten | 15.6 | 2958 | 29,600 |
| Azinphos-methyl, 1989 (1) | Peaches Sutter County | 33 | 0.62 | ten | 15.5 | 3,119 | 31,200 |
| Azinphos-methyl, 1990 (1) | Peaches Sutter County | 52 | 0.36 | eleven | 12.0 | 4,174 | 45,900 |
| Azinphos-methyl, 1990 (1) | Peaches Sutter County | 53 | 0.61 | eleven | 14.0 | 2,877 | 31,600 |
| Azinphos-methyl, 1989 (1) | Peaches Stanislaus County | 60 | 0.009 | eight | 0.44 | 6,111 | 48,900 |
| Azinphos-methyl, 1989 (1) | Peaches Stanislaus County | 61 | 0.011 | nine | 1.25 | 14,205 | 127,800 |
| Azinphos-methyl, 1989 (1) | Peaches Stanislaus County | 62 | 0.07 | eight | 4.30 | 7,679 | 61,400 |
| Phosmet 1989 (1) | Peaches Stanislaus County | 34 | 2.5 | eight | 28.17 | 1,409 | 11,300 |
| Phosmet 1989 (1) | Peaches Stanislaus County | 35 | 2.5 | eight | 31.6 | 1,579 | 14,200 |
| Phosmet 1989 (1) | Peaches Stanislaus County | 36 | 2.5 | eight | 39.3 | 1,964 | 15,700 |
| Phosalone 1976 (2,3) | Peaches Stanislaus County | 13-15 | 2.90 | six (5) | 76.0 | 3,276 | 19,700 |
| Phosalone 1977 (2,3) | Peaches Stanislaus County | 7-9 | 3.59 | six (5) | 67.2 | 2,340 | 14,000 |
| Phosalone 1977 (2,3) | Peaches Stanislaus County | 22-24 | 0.90 | six (5) | 57.2 | 7,944 | 47,700 |

## Table I(cont) Estimation of a Generic Transfer Factor For Tree Crop Harvesters From Dermal Exposure and Dislodgeable Foliar Residue Data

| Pesticide and year applied(a) | Crop and application site | No. of days post application(b) | Observed DFR (µg/cm2)(c) | No. of workers Monitored(d) | Mean dermal exposure per harvester (mg/8 hour workday) | Transfer factor for harvesters (cm2/hour)(e) | Total foliage contacted by all harvesters in crew (cm2/hour)(f) |
|---|---|---|---|---|---|---|---|
| Phosalone 1977 (2,3) | Peaches Stanislaus County | 3-5 | 2.89 | six (5) | 111 | 4,810 | 28,900 |
| Azinphos-methyl 1976 (2,3) | Peaches Stanislaus County | 22-24 | 0.20 | six (5) | 12.3 | 7,689 | 46,100 |
| Propargite 1988 (4) | Peaches Fresno County | 34 | 0.59 | ten | 5.17 | 1,095 | 11,000 |
| Propargite 1988 (4) | Peaches Fresno County | 39 | 0.54 | ten | 5.55 | 1,285 | 12,900 |
| Propargite 1988 (4) | Peaches Fresno County | 45 | 0.48 | ten | 3.65 | 950 | 9,500 |

**Weighted Mean Transfer Factor for all Data = Sum of Total Foliage Contacted by All Harvesters in Each Study divided by the Total Number of Workers Monitored in All Studies.**
**= 4023 ug$^2$/hour**

(a) Sources of data.
(1) Spencer et al., 1993.
(2) Popendorf et al., 1979.
(3) Popendorf and Leffingwell, 1982.
(4) Rech, 1989.
(b) The number of days after the pesticide application when the dislodgeable foliar residue samples were taken.
(c) DFR = Dislodgeable Foliar Residues. The DFR reported in Popendorf and Leffingwell (1982) were divided by 2 to calculate the DFR for both sides of the leaf.
(d) The number of harvesters monitored for dermal exposure with patch dosimetry for a 4-8 hour exposure period per workday.
(5) Each worker (ten total) only wore two patches and the patches were pooled at the end of workday to approximate the total dermal exposure for two workers. Therefore, each harvest day was considered two workdays.
(e) Formula for calculating Transfer Factor:
Mg of dermal exposure per workday X 1,000 ug/mg divided by observed DFR X 8 hr/day.
(f) Calculated by multiplying the number of workers monitored by the transfer factor.

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